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AIR-PRUNING TRAY/CONTAINER MATRIX TRANSFER AND TRANSPLANTING SYSTEMS AND METHODS

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AIR-PRUNING TRAY/CONTAINER PLANT TRANSFER AND TRANSPLANTING SYSTEMS AND METHODS

FIELD OF THE INVENTION

The present invention relates to plant trays/containers, systems and methods of matrix transfer and transplanting of plants/seedlings/plugs to increase plant yields, quality, production efficiency and to reduce the high labor requirement of plant transfer and transplanting to achieve automation of cultural and operational practices both in the field and greenhouse. It related more particularly to a push-pull air-pruning tray/container structure that allows effective root air-pruning for superior plant growth and that allows plant removal either from the open bottom of the tray or open top of the trays/containers. The present invention further related to a mechanically, pneumatically, hydraulically and/or electrically induced multiple plant/seedling/plug transfer and transplanting systems and methods for matrix transplanting one or more plants/seedlings/plugs from supply trays to the field or to containers using air-pruning trays as integrated components of the matrix transfer and transplanting system.

BACKGROUND OF THE INVENTION

The rapid increases in demands for higher unit area production and quality crops with less labor have opened worldwide demands for full integration and interfacing of new plant culturing practices and machine systems. Billions of plants/seedlings/plugs/cuttings are transplanted yearly in various sectors of agriculture and forestry with tremendous amount of human labor, causing a major bottleneck in the production systems. Mechanization and automation are as important for plant-growers/farmers as it is for any other field of agriculture. This is because there is a tremendous amount of labor involved in the operation of a nursery, and the growers/farmers have to contend with the problems of production efficiency, scarcity of labor and overall labor costs just as any other business.

In seedling culturing practices one particular labor-intensive area is that of transferring and transplanting relatively young and small plants from their initial rooting containers to larger plant containers or to the field for further growth and development. A great deal of nurseries and plant producing facilities generally perform this operation by hand. Consequently, plant transfer

and transplanting are time consuming and very inefficient. As a practical matter, the use of manual labor to transplant such plants severely limits the capacity of a farm or nursery for handling such transfer or transplanting operations. Therefore, there is and continues to be, a need for a fully automatic plant transfer and transplanting system that will automatically transfer and transplant plants/seedlings/plugs from an initial growing tray/container to a transfer area or second container for further growth and development in order to produce a superior plant in a greenhouse or in the field. Labor cost and availability, high costs of automation, as well as the inherent difficulties of plant/seedling/plug/cutting handling with a mechanical gripper (the main cause of misses, damages and unreliability) are the key problems to be resolved.

The innovative plant root-air-pruning technologies invented by Dr. Barney K. Huang have demonstrated many advantages including: elimination of root-binding, promotion of properly oriented root-branching for increased root-mass and vigorous growth, increased yields and quality, increased utilization cycles of greenhouse facilities, and savings on growth media, energy and fertilizer. The root-air-pruning concept allows the development of unique trays that lends itself to a simple automated/robotic transplanting system such as that disclosed by Dr. Barney K. Huang in U.S. Pat. Nos. 5,179,800, 5,254,140, 5,298,041, 5,573,558 and 6,357,180. Air-pruning tray-cells/pots has open bottoms with detachable screens. The tray-cells/pots are larger at the bottom and smaller at the top to eliminate the inherent disadvantages of traditional tray-cells/pots that have smaller closed bottom with drain hole(s) and larger open top that makes the container-sidewall tapered outward toward the top resulting in improper sidewall angle to cause root binding (root spiraling and tangling), slow and non-uniform growth.

The air-pruning tray-cell/pot/container design also utilizes the plant shoot characteristic that allows the foliage to fold together to go through the cell opening as the plant is pulled from the bottom or pushed from the top. This plant characteristic lends itself to an easy dislodging of the plant from the open cell/pot bottom and to the fully automated transplanting without using any types of grippers. Practical large scale field applications indicated that air-pruned cuttings and seedlings are significantly superior in growth performance both in the trays/containers and after transplanting and that effective fully automatic transplanting can be performed with the air-pruned plants/seedlings/plugs for various crops. However, many growers/farmers currently own transplanting machines and equipment, which were designed for traditional trays/flats/pots, yet, they want to use air-pruning trays/flats/pots which provide them with increased plant production,

quality and yields. Therefore, there has been and continues to be a need for air-pruning trays/flats/pots that effectuate air-pruning but will allow the plugs/seedlings/plants to be removed from the top of air-pruning trays/flats/pots.

SUMMARY AND OBJECTS OF THE INVENTION

The present invention entails plant growing air-pruning trays/pots/containers and the matrix transfer and transplanting systems and methods that are designed to overcome the disadvantage and shortcomings of many prior arts. In particular, the air-pruning trays/pots/containers of the present invention is provided with tray-cell/pot/container structure that allows plant removal either from the open bottom of the tray/pot or open top of the tray/pot and with a detachably supporting bottom screen that effectuates root air-pruning. The manually, mechanically, pneumatically, hydraulically and/or electrically actuated plant transfer and transplanting system is operative to receive air-pruning supply trays having a plurality of plants/seedlings/plugs therein, transferring and transplanting one or more plants/seedlings/plugs at a time from the supply trays utilizing push-rod or impulse type vacuum forces or other means to remove plants/seedlings/plugs from tray-cells/pots and eject or push them onto transfer areas such as the field ground or other plant containers.

It is therefore an object of the present invention to provide an air-pruning tray/pot/container structure that allows plant removal either from the open bottom of the tray/pot or open top of the tray/pot and with a detachably supporting bottom screen that effectuates root air-pruning. It is also an object of the present invention to provide a simple and low cost plant transferring and transplanting system for transplanting one or more plants/seedlings/plugs from one container or a supply tray/pot to a transfer area or second container.

Another object of the present invention resides in the provision of an automatic transferring and transplanting system that utilizes an intermittent or impulse vacuum system for inducing the movement of a plant/ plug or a plurality of plants/seedlings/plugs from a supply tray/pot to the field or containers to achieve fully automated transplanting.

Another object of the present invention is to provide a matrix transfer and transplanting system for automatically transferring groups of plants/plugs from an open bottom supply tray/pot by manually, mechanically, pneumatically, hydraulically and/or electrically pushing selected plants from and through the open bottom of the supply tray,

A further object of the present invention is to provide a manual or automatic plant transfer and transplanting system using air-pruning trays as integrated components of the matrix transfer and transplanting method for the system. One group of plants forming a matrix within one or a group of supply air-pruning trays is transferred and thereafter the entire supply tray or trays is sequentially shifted to a second position such that another like matrix of plants can be transferred and wherein this process is continued until the entire supply tray or trays are emptied.

Still a further object of the present invention is to provide an automatic plant transfer and transplanting system that is relatively simple and portable in construction and which is reliable and easy to use.

Other objects and advantages of the present invention will become apparent and obvious from a study of the following description and the accompanying drawings, which are merely illustrative of such invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the matrix transfer and transplanting system of the present invention illustrating that air-pruning trays (supply trays) are integrated components of the system and that it can transplant 2 pots at a time using 2 impulse vacuum systems or 2 flats at a time using 2 sets of push rods arranged in matrix formation.

FIG. 2 shows the operational principle of the plant transfer and transplanting system of the present invention illustrating that the plant is instantly dislodged downward with impulse vacuum as the open bottom of tray-cell matches the opening of indexing table and suction tube.

FIG. 3 shows the operational principle of the plant transfer and transplanting system of the present invention illustrating that multiple plants are instantly dislodged downward and transplanted into multi-air-pruning-pot flat with push-rod forces as the open bottoms of tray-cells match the openings of indexing table.

FIG. 4 shows the pneumatically or hydraulically activated impulse vacuum system of the present invention with suction tube at the center of round bellow (with flexible door at the end) activated by two cylinders to generate impulse vacuum.

FIG. 5 shows the pneumatically or hydraulically activated impulse vacuum systems of the present invention with a square pyramid shaped bellow.

FIG. 6 through FIG. 11 are a sequence of front elevation views of an automatic transplanter of the present invention illustrating a series of matrix plant transfers and transplanting from an air-pruning supply tray to an underlying multi-pot receiving flat with **FIG. 6** illustrating the initial positions of upper and lower indexing tables, relative locations of air-

pruning trays, underlying flats, pushers and dibblers. The first flat has been dibbled, and the second flat is ready to be dibbled by moving the lower table upward; **FIG. 7** illustrating the dibbling operation is completed for the second flat while the first flat is ready for transplanting. The upper and lower tables move upward together to complete the transplanting operation for the first flat with the stationary pushers above; **FIG. 8** illustrating both tables being moved upward to a preset point so that all seedlings for the first flat are transplanted by pushers to flat soil level in one operation. While pushers hold down the seedlings, the upper table moves upward to a preset point to clear the seedlings; **FIG. 9** showing the transplanting operation for the first flat and dibbling operation for the second flat are completed and both tables are moving downward back to the initial table positions shown in **FIG. 6**; **FIG. 10** showing both tables are at the initial position and the first flat is ready to be conveyed out, allowing the second flat moving into transplanting position and the third set of flat to be conveyed into dibbling position; and finally **FIG. 11** illustrating the first flat is conveyed out and the second flat is ready for transplanting and the third flat is ready to be dibbled.

FIGS. 12 and 13. respectively illustrate the beginning and final positions of 288-cell air-pruning tray being sequentially indexed for **matrix** transfer and transplant 2 x 4 multi-pot flat or 8 plants at each indexing.

FIGS. 14 and 15. respectively illustrate the beginning and final positions of 288-cell air-pruning tray being sequentially indexed for **matrix** transfer and transplant 3 x 6 multi-pot flat or 18 plants at each indexing.

FIGS. 16 and 17. respectively illustrate the beginning and final positions of 288-cell air-pruning tray being sequentially indexed for **matrix** transfer and transplant 4 x 8 multi-pot flat or 32 plants at each indexing.

DETAILED DESCRIPTION OF THE INVENTION

With reference to **FIG. 1,** the automatic matrix transfer and transplanting system of the present invention indicated generally by the numeral **100;** includes the push-pull air-pruning trays **10**, the upper indexing table **20** with interchangeable opening plates **21** and matching dibbler plates **22**, the X-Y indexing frame **23**, the lower indexing/conveying table **30**, the indexing/conveying belt **31**, supporting frame **40**, detachable impulse vacuum systems **50**, and interchangeable push-rod plates **60** and pushers **61**. As will be appreciated from subsequent portions of this disclosure, the plant/plug supply tray **10** forms a part of the transplanting system designed to transfer one or more plants at a time from a supply tray to a receiving area such as pots, multi-pot flats or the field environment.

The matrix transfer and transplanting system **100** is designed to receive a supply trays **10** that includes an open top and bottom and a plurality of aligned and uniformly spaced truncated

pyramid or generally cone shaped plant cells **11** formed in the tray. Matrix transfer and transplanting system **100** is designed to transfer respective plants/seedlings/plugs from supply tray **10** to the plant receiving areas in matrix formation, which can be individually separated pots, multi-pot flats, and the field environment.

Turning now to a discussion of matrix transfer means **100**, the same comprises a supply tray holding and indexing means **23**, upper indexing table **20** that includes therein opening means **21** as shown in **FIGS. 2** and **3**. Opening means **21** could include a single opening or a plurality of openings that are particularly spaced with respect to the individual cells **11** of the supply tray **10**. This allows selecting cells **11** of the supply tray **10** to align with matrix openings **21** when the supply tray assumes a selected position thereover. In any event, as will be understood and appreciated from subsequent portion of this disclosure, the function of the opening means **21** is to permit selected plants/seedlings/plugs to pass therethrough as they are dislodged from the supply tray cells **11**. To contain and control the supply tray **10**, matrix transfer system **100** comprises X-Y type indexing frames **23** shown in **FIG. 1**. The frames are movably mounted over the table **20** of the matrix transfer system **100** for receiving, holding and indexing supply tray **10**. Indexing frames can be indexed in X or Y direction about the table **20** using electrical, hydraulic, pneumatic, mechanical and/or manual means.

Also forming a part of the matrix transfer means of the present invention is the lower indexing/conveying table **30** and indexing/conveying belt **31**. It functions to transfer the respective plant receiving means **32** to an appropriate planting position under the suction tubes **51** or pushers **61** where the transfer of plants actually takes place; and under the dibblers **22** where the dibbling of growth media takes place. It is appreciated that the indexing/conveying belt **31** would be operated in time relationship to the indexing frame **23**. In this regard it should be appreciated that matrix transfer system **100** of the present invention is designed so as to plant all of the underlying plant receiving means **32** at the same time with single-/multi-tubes or single-/multi-pushers for one-/multi-plants at a time with the indexing/conveying table **30** and indexing/conveying belt **31**. Once the underlying plant receiving means **32** has been planted, then the indexing/conveying belt **31** is operative to advance those plants and associated containers from a planting position underneath the upper indexing table **20**. Right after the planted containers have been moved from the planting position underneath the upper indexing table **20**, the indexing/conveying belt **31** is operative to advance a next group of containers to the

planting position underneath the upper indexing table **20**.

Turning now to **FIG. 4**, which shows the pneumatically or hydraulically activated impulse vacuum system of the present invention indicated generally by the numeral **50**. The suction tube **51** is attached at the upper center of round bellow **52** and the lower end is attached to the telescoping tube inside the bellow with a flexible door **53** at its end. The bellow **52** is activated by two cylinders **54** to generate impulse vacuum at the suction tube **51** as the bellow **52** is expended by activating the cylinders **54** which causes the flexible door **53** to close automatically. The alternative square pyramid shaped bellow **52** and the means of activation is shown in **FIG. 5**. The pyramid shaped bellow **52** tends to provide a larger initial impulse vacuum.

Turning to the operation of the matrix transfer and transplanting system **100** of the present invention, reference is first made to **FIG. 6 through FIG. 11** that illustrate a sequence of automatic transplanting illustrating a series of matrix plant transfers and transplanting from an air-pruning supply tray **10** to an underlying multi-pot receiving flat **32**. The sequence of plant transfer and transplanting starts with **FIG. 6** illustrating the initial positions of upper and lower indexing tables **20** and **30**, relative locations of air-pruning trays **10**, underlying flats **32A** and **32B**, pushers **61** and dibblers **22**. The first flat **32A** has been dibbled, and the second flat **32B** is ready to be dibbled by moving the lower table **30** upward; **FIG. 7** illustrating the dibbling operation is completed for the second flat **32B** while the first flat **32A** is ready for transplanting. The upper and lower tables **20** and **30** move upward together to complete the transplanting operation for the first flat **32A** with the stationary pushers **61** above; **FIG. 8** illustrating both tables **20** and **30** being moved upward to a preset point so that all seedlings for the first flat **32A** are transplanted by pushers **61** to flat soil level in one operation. While pushers **61** hold down the seedlings, the upper table **20** moves upward to a preset point to clear the seedlings; **FIG. 9** showing the transplanting operation for the first flat **32A** and dibbling operation for the second flat **32B** are completed and both tables **20** and **30** are moving downward back to the initial table positions shown in **FIG. 6**; **FIG. 10** showing both tables **20** and **30** are at the initial position and the first flat **32A** is ready to be conveyed out, allowing the second flat **32B** moving into transplanting position and the third flat **32C** to be conveyed into dibbling position; and finally **FIG. 11** illustrating the first flat **32A** is conveyed out and the second flat **32B** is ready for transplanting and the third flat **32C** is ready to be dibbled.